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DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

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INTERNATIONAL APPLICATION NO.
PCT/GB00/01508INTERNATIONAL FILING DATE
18 April 2000PRIORITY DATE CLAIMED
19 April 1999

TITLE OF INVENTION

ACTIVE MATERIAL LOW POWER ELECTRICAL SWITCHING MECHANISM AND DRIVE CIRCUIT
THEREFOR

APPLICANT(S) FOR DO/EO/US

Simon POWELL

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Notice of Priority,

Request for Consideration of Documents Cited in the International Search Report

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Rec'd PCT/PTO 24 MAR 2003

215159US-2 PCT

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF

SIMON POWELL : ATTN: APPLICATION DIVISION

SERIAL NO: 09/926,352 :

FILED: OCTOBER 19, 2001 :

FOR: ACTIVE MATERIAL LOW POWER
ELECTRICAL SWITCHING
MECHANISM AND DRIVE
CIRCUIT THEREFOR

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Prior to a first examination on the merits, please amend the above-identified application as follows:

IN THE CLAIMS

Please amend the claims as follows:

3. (Amended) A drive circuit according to Claim 1, and further comprising voltage multiplying means arranged to multiply the output drive voltage to an operational level.

4. (Amended) A drive circuit according to claim 1, wherein said transformer is arranged to saturate at 50% of the current imbalance level indicative of a fault condition.

5. (Amended) A drive circuit according to claim 1, wherein said first primary coil and said second primary coil are each provided with n_1 turns, and said secondary coil is provided with n_2 turns, wherein $n_2 > n_1$.

6. (Amended) A drive circuit according to claim 1, wherein said output drive voltage is used to actuate an active material bender.

7. (Amended) An electrical switching mechanism comprising a drive circuit according to claim 1 arranged to drive an electrical actuator means; the mechanism further comprising an electrical switching means arranged to open one or more electrical contacts provided in an electrical circuit in response to said electrical actuator means when the drive circuit detects a fault condition in the electrical circuit.

9. (Amended) A mechanism according to claim 7, wherein the electrical actuator comprises a planar active material bender.

12. (Amended) A mechanism according to claim 9, and further comprising a planar spacer member laminated between said planar active material bender and said planar frame member.

13. (Amended) A mechanism according to claim 8, wherein said latching means comprises a rotatable pawl arranged to latch the slider member when held in a first position by the electrical actuator.

15. (Amended) A mechanism according to claim 8, wherein said profiled channel is provided with a first angled latching surface and the slide member is provided with a second angled latching surface, the arrangement being such that said second angled latching surface is held in slidable meeting engagement with said first angled latching surface when said slide member is latched.

16. (Amended) A mechanism according to claim 8, further comprising a spring means arranged to bias said slide member out of said profiled channel.

IN THE ABSTRACT

A drive circuit for a residual current device includes a transformer having a first and second primary coil each having n_1 turns, and a secondary coil having n_2 turns arranged to output a drive voltage responsive to any current imbalance between the respective electric currents flowing in the first and second primary coils. In order to achieve as high a drive voltage as possible the transformer is arranged to saturate at a relatively low level of current imbalance thus causing the back-EMF voltage generated across the secondary coil to spike resulting in a low power high voltage drive signal being output. Preferably, the secondary coil output is rectified, smoothed, and multiplied before being used as a drive signal for an active material bender used as an actuator in a circuit breaker mechanism.

REMARKS

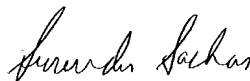
Favorable consideration of this application, as presently amended, is respectfully requested.

The present Preliminary Amendment is submitted to place the above-identified application in more proper format under United States practice. By the present Preliminary Amendment, the claims has been amended to no longer recite any improper multiple dependencies. A new Abstract is also submitted herein.

The present application is believed to be in condition for a full and thorough examination on the merits. An early and favorable consideration of the present application is hereby respectfully requested.

Respectfully submitted,

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ACTIVE MATERIAL LOW POWER ELECTRICAL
SWITCHING MECHANISM AND DRIVE CIRCUIT THEREFOR

TECHNICAL FIELD

5 The present invention relates to electrical switching mechanisms and more particularly to such mechanisms when used in electrical safety equipment such as residual current circuit breakers, and to an electrical drive circuit suitable for use with such mechanisms.

BACKGROUND OF THE INVENTION

10 In our earlier international application WO-A-98/40917, we have disclosed a novel form of electrically activated mechanical release mechanism which we have termed an actuator which improves the displacement behaviour of active material benders using materials such as piezo-ceramics. A feature of all active materials is that they are relatively inefficient, having coupling factors
15 between the driving means and the output of fractions of a percent. Consequently, actuators which use such materials tend to require high fields be they magnetic or electric. However, we have found that despite this disadvantage, an actuator utilising an active material bender can result in a product having good mechanical properties.

20 The area of interest in this invention is the field of Residual Current Devices, known as RCDs. This term covers Residual Current Circuit Breakers which are not equipped with current limiting capabilities and Residual Current Breakers with Overload which have current limiting portions.

 RCDs function by comparing the current flowing within the live and
25 neutral conductors, on the principle that it should be equal and opposite. A variation in the currents indicates a leakage from the circuit which is usually indicative of a fire risk or a human in danger of electrocution.

 RCDs are manufactured in many formats, such as adaptors, plugs, electric socket outlets and consumer unit devices. In performance terms, devices

can be divided into two specific types.

Line Dependent devices use electronic processing to measure the differential current and to then trigger an actuator that causes the circuit to be opened. These devices benefit from being flexible and consistent, because their trip level can be set by the selection of threshold resistors, and the tripping action is not reliant upon the energy within the fault, as the electronics can call upon the mains supply to power the actuator.

Line independent devices utilise the energy from the fault itself to initiate the tripping action. This is most commonly achieved through the use of a permanent magnet relay. The principles of permanent relays are well-known, but to summarise a movable metal part is held in a first position by means of a suitable permanent magnet which is surrounded by a coil. When a fault current flows it induces a current within a toroidal transformer connected to the coil surrounding the magnet. The current flow is rectified such that its associated magnetic field opposes that of the permanent magnet until the movable piece is freed. In order to make highly sensitive relays the mating surfaces of the metal parts must be of exceptional flatness, and the system must be totally clean. The flattening and assembly processes are consequently expensive.

Our International Application WO98/40917 discloses a novel form of actuator suited to active materials, termed a planar bimorph. The same application also discloses a methodology for using such actuators to release mechanisms. Such systems require a large voltage in order to operate, and such voltages cannot presently be generated in line independent systems.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an inductive circuit capable of producing a low-power high-voltage drive signal which can be used to drive a line-independent electrical switching mechanism.

It is a further object of the present invention to provide an electrical switching mechanism which is driven by an inductive circuit where output is

converted into a high voltage.

In order to meet the above objects, according to a first aspect of the present invention there is provided a drive circuit for a residual current device, the circuit comprising a transformer having a first primary coil and a second primary coil, and a secondary coil arranged to provide an output drive voltage in response to any current imbalance between the respective electric currents flowing in the first and second primary coils; the transformer being further arranged to saturate at a level of current imbalance less than a level indicative of a fault condition.

In a preferred embodiment of the drive circuit according to the first aspect of the present invention, there is further provided voltage rectifying means arranged to rectify the output drive voltage. In addition, the preferred embodiment preferably further comprises voltage multiplier means arranged to multiply the output drive voltage to an operational level.

Furthermore, the saturation level of the transformer is preferably much lower than the current imbalance level indicative of a fault condition, and in a preferred embodiment the transformer is arranged to saturate at 50% of the current imbalance level indicative of a fault condition in an electrical circuit to which the drive circuit of the present invention is connected.

Preferably, the first primary coil and the second primary coil are each provided with the same number n_1 turns, and the secondary coil is provided with n_2 turns, wherein n_2 is greater than n_1 , the coupling between the primary coil and the secondary coil therefore providing a step-up in the voltage across the secondary coil with respect to the primary coils.

The output drive voltage produced by the drive circuit of the present invention is preferably used in a preferred embodiment to actuate an active material bender manufactured from piezo-ceramics.

It is a feature of the drive circuit according to the first aspect of the present invention that the saturation of the transformer at a level of current imbalance less than the trip level causes a large back-EMF to be generated across

the secondary coil with each saturated pulse. This feature provides the advantage that the generated back-EMF, which is of a high voltage, but low power, can be used to drive an active material bender manufactured from piezo-ceramics, which generally requires a low power high voltage electric field for correct operation.

5 In addition to providing a drive circuit, according to a second aspect the present invention also provides an electrical switching mechanism comprising a drive circuit according to the first aspect of the present invention arranged to drive an electrical actuator means; the mechanism further comprising an electrical switching means arranged to open one or more electrical contacts provided in an
10 electrical circuit in response to said electrical actuator means when the drive circuit detects a fault condition in the electrical circuit.

From the second aspect, the electrical switching means of the electrical switching mechanism preferably comprises a planar frame member provided with a profiled channel, a planar slide member arranged to be received
15 within the profiled channel, and latching means arranged to latch the planar slide member within the profiled channel, the latching means being responsive to the electrical actuator means to latch or release the slide member to close or open the one or more electrical contacts.

Preferably, the electrical actuator means comprises a planar active
20 material bender as disclosed in our earlier international application no. WO98/40917, the necessary features of which required for understanding the present invention being incorporated herein by reference.

In a preferred embodiment, the planar active material bender is arranged to be laminated to the planar frame member in order to produce a low
25 profile device. In such a construction, the active material bender when acting as the electrical actuator is further arranged to move out of the plane of action of the latching means upon actuation.

Furthermore, in the particularly preferred embodiment, the latching means comprises a rotatable pawl arranged to latch the slide member when held

in a first position by the electrical actuator. When the electrical actuator comprises the active material bender, as the active material bender moves out of the plane of action of the latching means upon actuation, the rotatable pawl is freed to rotate to allow the slide member to release.

5 In the preferred embodiment of the electrical switching mechanism according to the second aspect of the present invention, a spring means is further provided arranged to bias the slide member out of the profiled channel provided in the frame member.

10 It is a feature of the electrical switching mechanism according to the second aspect of present invention that a relatively large mechanical movement in the form of the release of the slide member can be obtained from a relatively small movement of the electrical actuator means. This has the advantage that the mechanism of the present invention is particularly suitable for use with active material benders using material such as piezo-ceramics which require high drive
15 fields to produce relatively little movement. It is a further advantage of the present invention that the relatively large movement of the slide member upon release can be used to trigger a further mechanism such as, for example, a circuit breaker mechanism.

BRIEF DESCRIPTION OF THE DRAWINGS

20 In order that the present invention be more readily understood, embodiments thereof will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a circuit diagram of a preferred embodiment of a drive circuit according to the first aspect of the present invention;

25 Figure 2 shows an exploded perspective view of a release mechanism which can be used as the switching mechanism according to the second aspect of the present invention;

Figure 3 shows a cross-section of the assembled release mechanism of Figure 2 along the line A-A and looking in the direction of the arrows; and

Figure 4 is a circuit block diagram illustrating the interaction between the drive circuit and the switching mechanism of the present invention

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As will be apparent from the preamble, the present invention has two aspects, being respectively a drive circuit, and an electrical switching mechanism which employs the drive circuit for generation of the necessary drive voltage. A preferred embodiment of the drive circuit according to the first aspect of the present invention will now be described with respect to Figure 1.

In Figure 1, a drive circuit according to the preferred embodiment of the present invention comprises a toroidal transformer 70 having a first primary coil 66 arranged to carry a load current i_l from the live contact of a voltage source 64 such as, for example, the mains, to a load 74. The first primary coil 66 consists of a single turn around the toroidal core of the transformer 70. A second primary coil 72 is further provided consisting of a single turn around the toroidal core, and arranged to carry a current i_n from the load 74 back to the neutral contact of the voltage source 64. In addition to the first and second primary coils, a secondary coil 68 comprising a plurality of turns around the transformer core is further provided on the core of the toroidal transformer 70. An induced output voltage E across the secondary coil 68 being fed to a diode bridge rectifier 76 for rectification, the rectified output drive voltage from the secondary coil 68 then being passed to a voltage multiplier 61 for voltage multiplication of the output drive voltage E to an operating voltage V . In the preferred embodiment, a smoothing capacitor 78 is further provided connected across the output of the diode bridge rectifier 76 in order to smooth the rectified voltage prior to multiplication in the voltage multiplier 61. The voltage multiplier 61 may be any convenient multiplication means or circuit elements apparent to the man skilled in the art.

Although within the preferred embodiment described above and shown in Figure 1 the output drive voltage E from the secondary coil is shown as

being rectified by the diode bridge rectifier 76 prior to multiplication in the multiplier 61, this order is not essential to the operation of the present invention, and it may of course be possible that the order of the rectifier 76 and the multiplier 61 be reversed, in that the AC voltage output from the secondary coil may be multiplied by the multiplier 61 prior to rectification by the bridge rectifier 76.

Furthermore, in other embodiments of the present invention, depending upon the application which the output drive voltage from the secondary coil is to be put, either one or other or both of the rectifier 76 (including the smoothing capacitor 78) and the voltage multiplier 61 may be omitted from the drive circuit of the present invention.

In the present embodiment, the drive circuit of the present invention operates as the sensing means on an RCD, and in particular the provision of the transformer allows for accurate current imbalance sensing, as will be explained more fully below. Preferably, the primary coils 66 and 72 comprise only a single turn, while the secondary coil 68 has a large number of turns, and typically more than 1000. High permeability materials such as Nickel Iron are used to increase the overall inductance of the system.

The drive circuit of the present invention having the aforementioned construction operates in the following manner. The voltage created across the secondary coil 74 of the toroidal transformer 70 is the back-EMF to oppose any change in the currents flowing in either of the primary coils, and is given by the well known equation $E = -L di/dt$. Under normal circumstances i.e. in the absence of a fault condition, the respective electric currents flowing in the live coil 66 (I_L) and the neutral coil 72 (I_N) are equal and opposite, so the magnetic fields associated with the respective currents cancel out, and thus there is little or no current induced in the secondary coil 68.

If a proportion of the incoming current I_L begins to flow out of the load due to a fault condition such as, for example, a short circuit or a human in danger of electrocution, the magnetic fields associated with the respective currents

flowing through the two primary coils cease to be equal and opposite, resulting in an induced voltage in the secondary coil 68. Initially, the induced waveform is sinusoidal with the same frequency and phase as the voltage supply 64 to match the fault current, but as the fault current increases the toroidal transformer is arranged to saturate and the output voltage waveform E across the secondary coil 74 becomes spiked. In traditional electro-mechanical relays this is a disadvantage, because the power delivered decreases. Piezo electric and electrostrictive materials however are distinctive in requiring very low power but being demanding of a high electric field in order to operate. As mentioned above, the voltage output of an inductor is calculated by the equation $E = -L \, di/dt$, where E is the Voltage, L is the system inductance and di/dt is the rate of change of current over time. The saturation of the magnetic core results in a very high di/dt and so the voltage across the secondary coil goes up. The present invention utilizes this behaviour in order to generate an initially high voltage from the toroidal transformer. Preferably, the magnetic core of the transformer is designed to saturate at a point around 50% of the trip value, the trip value being the level of current imbalance between the two primary coils indicative of a fault condition.

In the preferred embodiment shown in Figure 1, the induced voltage waveform E across the secondary coil is preferably rectified in a bridge diode circuit 76, and smoothed with a smoothing capacitor 78. The thus rectified and smoothed signal is then fed to a voltage multiplier circuit 61 for multiplication by a convenient factor such as two or three up to an operating level V. The output signal V may then be used to drive an electrical switching mechanism, as will be described later.

In an alternative embodiment of the drive circuit according to the first aspect of the present invention an oscillator circuit and appropriate control chip are further provided arranged to control the switching of the current through the secondary coil. Such operation is similar to that of a switched mode power supply, where the sudden switching off of the current in an inductor is used to

create a high voltage pulse, where the timing of the disconnection is governed by the voltage across a reference resistor. If such switching is undertaken very rapidly using the oscillator circuit, then high voltages can be created. By controlling the frequency and duty cycle of the oscillator then the necessary operating voltages can be obtained from the toroidal transformer. In order to achieve a suitable voltage it is also necessary to rectify the toroid output and also rectify the output from the drive chip. This is done using a diode bridge rectifier in both cases.

In addition to providing a drive circuit for an RCD, from a second aspect the present invention also provides an electrical switching mechanism which employs the drive circuit to indicate a fault condition and initiate switching, and a preferred electrical switching mechanism according to the second aspect of the invention will now be described with reference to Figures 2 and 3.

The electrical switching mechanism according to the present embodiment and shown in the accompanying drawings is constructed from a number of layers of sheet material. The relative thicknesses of the different layers are chosen having regard to the different functions to be performed by the layers and this also applies to the material utilised. For ease of handling in this particular construction, the material is metal strip in which the thickness is readily controlled to acceptable limits by the fabrication process. Thicknesses of 0.15 millimetres to 0.2 millimetres have been found to be suitable but other thicknesses can be used as can other materials for certain of the layers. It is not necessary for the layers to be metal or conductive and in fact, in some instances it may well be an advantage for the layers to be insulative or self lubricating by being manufactured from a suitable plastics material.

The switching mechanism according to the preferred embodiment of the present invention comprises a substrate 10 to which are attached a stack of other layers the stack comprising a frame 12, a spacer 14, and a planar bimorph layer 16 in that order from the substrate 10. A slider element 18 is further provided arranged to slide within a profiled channel 30 formed in the frame 12 and

the slider is formed with an extension 32 which extends beyond the open end of the profiled channel 30 in the frame 12.

The slider 18 is formed with a slot 34 provided in the extension 32, the slot being arranged to receive a spring 36, with one end of the spring being located on a spring seat 37 provided with the slot, with the other end of the spring 36 in engagement with a spring seat 38 provided on one of the other layers, and in this case the spacer layer 14. The slider member is capable of being latched against the action of the spring 36 by means of a rotatable pawl 40. The pawl 40 is mounted for rotation by means of a bearing 41 provided in the preferred embodiment on the spacer 14 but which may also be provided on the substrate 10. The spacer is also further provided with an aperture 42 through which the operable, movable tip 44 of the piezo bimorph extends in order to control the rotation of the pawl 40 and thus the release or latching of the slider 18.

Before describing the operation of the above described mechanism, it is important to understand that the profiled channel 30 in the frame 12 is specially shaped so that the slider 18, although being largely movable linearly in the direction of the arrow X under the action of the spring 36 is also capable of slight lateral or rotational motion. Also, the profiled channel narrows near the open end 64 of the channel so as to restrict the stroke of the slider which is formed with protrusions 46 wider than the narrow open end of the channel 64. Also, the pawl 40 has a semi circular portion 48 arranged to be received in a corresponding portion 50 of the profile channel so as to be capable of angular movement in the direction of the arrow A (shown as clockwise within the drawing) within the profile channel. The pawl is further formed with a shaped recess 52 arranged to receive a correspondingly-shaped projection 54 on the end of the slider 18 remote from the spring 36. The shape and size of the meeting projection 54 and recess 52 are carefully designed to provide a specific burst force and the slider is also provided with an additional angled latching surface 56 arranged to slidably engage a corresponding angled latching surface 58 provided on the frame 12. The angles

of the respective latching surfaces 56 and 58 are such that the force exerted by the spring 36 upon the slider 18 when the slider 18 is latched causes the latching surface 56 to press against the latching surface 58, the reaction force generated by the latching surface 58 causing a turning moment to be applied to the slider 18 in the direction of the arrow B, shown as anticlockwise on the drawing.

Figure 3 illustrates a cross-section of the various layers when assembled. With reference to Figure 3, it will be seen that the piezo-bimorph 16 is provided with a pin member 44 which extends through aperture 42 provided in the spacer to engage with the pawl 40. Typically, the pin member 44 corresponds to the depth of the spacer 14 and the slider 18, and this is typically 0.35mm. The pin member 44 is provided on the operating end of the piezo-bimorph 16 such that when the piezo-bimorph 16 is actuated the pin member 44 is moved out of the plane of rotation of the pawl 40 in the direction of the arrow C to such an extent that the pawl 40 becomes free to rotate in the direction of the arrow A. Within Figure 3 the pawl 40 is shown mounted on a bearing 41 (not shown) provided on the spacer 14, although it will also be possible to provide the bearing 41 on the substrate 10.

Turning now to the operation of the mechanism, let us assume that the various layers are all assembled, stacked one on top of the other as shown in Figure 3, with the slider in position in the channel 30 such that the latching surface 56 is in engagement with the latching surface 58 on the frame 12 and the spring 36 is thus in compression between the spring seats 37 and 38. The surfaces 56 and 58 are angled such that the spring force is converted into a rotational force as indicated by the arrow B. This rotation is restricted by virtue of the projection 54 on the slider 18 being restrained by the recess 52 in the pawl 40. Movement of the pawl 40 in the direction of the arrow A is restricted by virtue of the pin member 44 provided on the moveable end of the piezo bimorph 16.

When the mechanism is to be actuated, an electrical signal is applied to the piezo bimorph 16 which causes the bimorph to flex in such a way that the

pin 44 is pulled upwards, out of the plane of the paper in Figure 2 and in the direction of the arrow C in Figure 3, and out of an engagement with the pawl 40. The shape of the meeting surfaces of the projection 54 and recess 52 in combination with the shape of the meeting surfaces 56 and 58 under the action of the force exerted by the spring 36 causes the slider 18 to start to pivot in the direction of the arrow B which in turn forces the pawl 40 to rotate in the direction of the arrow A until such time as the pawl 40 releases the projection 54 which permits free movement of the slider 18 firstly in an arcuate direction in the direction of the arrow B and subsequently in the direction of the arrow X so that the extension 32 of the slider 18 can be used to activate a further mechanism or apparatus, such as a circuit breaker mechanism.

In order to reset and relatch the mechanism, it is assumed that there is no electric signal applied to the bimorph 16 so that the pin 44 is in its down most position. By moving the slider 18 against the spring 36 in the direction opposite to the direction X, the spring 36 is compressed and the slider is moved past the latching projection 58 to permit the projection 54 on the end of the slider to be received in the recess 52 in the pawl. The pawl is resiliently biased by a slight spring force in a direction opposite to the direction of the arrow A so as to permit the projection 54 to be captured by the recess and the pin 44 to hold the capture position.

It will be apparent from the above description that the reaction force generated by the latching surfaces 56 and 58 due to the compression of the spring 36, the burst force of projection 53 and recess 52, and the return spring force of the pawl 40 must all be carefully balanced in order to achieve correct operation. More particularly, whilst it will be apparent to the skilled reader that a large degree of variations can be accommodated, it will be appreciated that the sum of the return spring force acting to return the pawl 40 to the latch position with the burst force generated by the angled surfaces of the recess 52 and projection 54 must be less than the reaction force generated by the angled latching surfaces 56

and 58 under the compression of the spring 36 in order for the slider 18 to be released when the piezo-bimorph member 16 is actuated. If this condition is not adhered to, then the reaction force of the latching surfaces 56 and 58 will not overcome the burst force of the recess projection and the return force on the pawl, and the slider will not release.

Due to the small engagement depth and release force, it is possible to exploit the large motion of the planar bimorph to create a system which operates from a low power.

It will be appreciated that the above construction is capable of being manufactured to any dimensions. In fact, it is very suitable for micro-machining techniques due to the laminar nature of the structure. Furthermore, while the electrical actuator of the present invention has been described as a piezo-bimorph, other electrical actuators may be used, and in particular electric relays, armatures or moving-coil magnets. In particular, however, the drive circuit is particularly suitable for operating the piezo-bimorph, as it is capable of providing the high voltage fields required to operate an active material bender such as the piezo-bimorph.

Figure 4 shows a block diagram illustrating how the drive circuit according to the first aspect of the present invention and the electrical switching mechanism according to the second aspect of the present invention are integrated together. More particularly, with reference to Figure 4, a pair of contact switches 63 are provided in the live circuit between the toroidal transformer 70 and the load 74 arranged to break the live circuit and thus prevent current flowing through the coils of the toroidal transformer 70. The contacts 63 are mechanically linked to the electrical switching mechanism of the present invention labelled 62 in the diagram. More specifically, preferably the contacts 63 are mechanically linked to the extension 32 of the slider 18 of the electrical switching mechanism and arranged so that the electrical contacts 63 are opened when the slider 18 is released from its latched position within the profiled channel 30 such that the

extension 32 projects a substantial amount beyond the end of the channel 30. The contacts 63 may be directly mounted upon the extension 32 of the slider 18, or a mechanical linkage or further mechanism may be provided between the slider 18 and the electrical contacts 63.

5 In operation, therefore, assuming the electrical contacts 63 are closed and current is flowing through the load 74, the toroidal transformer 70 acts to detect any current imbalances between the current i_l and i_n flowing in the respective live and neutral lines by virtue of outputting the output drive voltage E, being the back-EMF across the secondary coil. The output voltage E is then
10 rectified if required and fed to the voltage multiplier 61 for multiplication up to the operating voltage V, the operating voltage V being arranged to be placed across the piezo-bimorph of bender 16 as appropriate in order to actuate the piezo-bimorph 16 to bend out of the plane of action of the pawl 40 thus releasing the slider 18 from the profiled channel 30 and opening the contacts 63.

15 This arrangement then constitutes a particularly effective low-power line independent device.

CLAIMS:

1. A drive circuit for a residual current device, the circuit comprising a transformer having a first primary coil and a second primary coil, and a secondary coil arranged to provide an output drive voltage in response to any current imbalance between the respective electric currents flowing in the first and second primary coils; characterised in that the transformer is further arranged to saturate at a level of current imbalance less than a level indicative of a fault condition, such that the output drive voltage from the secondary coil is caused to be at a higher voltage with lower power than otherwise.
2. A drive current according to Claim 1, and further comprising voltage rectifying means arranged to rectify the output drive voltage.
3. A drive circuit according to Claim 1 or 2, and further comprising voltage multiplying means arranged to multiply the output drive voltage to an operational level.
4. A drive circuit according to any of the preceding claims, wherein said transformer is arranged to saturate at 50% of the current imbalance level indicative of a fault condition.
5. A drive circuit according to any of the preceding claims, wherein said first primary coil and said second primary coil are each provided with n_1 turns, and said secondary coil is provided with n_2 turns, wherein $n_2 > n_1$.
6. A drive circuit according to any of the preceding claims, wherein said output drive voltage is used to actuate an active material bender.
7. An electrical switching mechanism comprising a drive circuit according to any of the preceding claims arranged to drive an electrical actuator

means; the mechanism further comprising an electrical switching means arranged to open one or more electrical contacts provided in an electrical circuit in response to said electrical actuator means when the drive circuit detects a fault condition in the electrical circuit.

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8. An electrical switching mechanism according to claim 7, wherein the electrical switching means comprises a planar frame member provided with a profiled channel; a planar slide member arranged to be received within the profiled channel; and latching means arranged to latch the planar slide member within the profiled channel, the latching means being responsive to the electrical actuator means to latch or release the slide member to close or open the one or more electrical contacts.

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9. A mechanism according to claims 7 or 8, wherein the electrical actuator comprises a planar active material bender.

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10. A mechanism according to claim 9, wherein the planar active material bender is laminated to said planar frame member.

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11. A mechanism according to claim 10, wherein the active material bender is further arranged to move out of the plane of action of the latching means upon actuation.

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12. A mechanism according to claim 9, 10 or 11 and further comprising a planar spacer member laminated between said planar active material bender and said planar frame member.

13. A mechanism according to any of claims 8 to 12, wherein said latching means comprises a rotatable pawl arranged to latch the slider member

when held in a first position by the electrical actuator.

14. A mechanism according to claim 13, wherein said rotatable pawl is further provided with a shaped recess arranged to receive a correspondingly shaped projection provided on the slide member wherein in a latched mode of operation said rotatable pawl is prevented from rotation by said electrical actuator such that said shaped projection is held within said shaped recess to latch said slide member, and in a released mode of operation the electrical actuator moves to allow said rotatable pawl to rotate, thereby freeing said shaped projection from said shaped recess to release said slide member.

15. A mechanism according to any of claims 8 to 14, wherein said profiled channel is provided with a first angled latching surface and the slide member is provided with a second angled latching surface, the arrangement being such that said second angled latching surface is held in slidable meeting engagement with said first angled latching surface when said slide member is latched.

16. A mechanism according to any of claims 8 to 15, further comprising a spring means arranged to bias said slide member out of said profiled channel.

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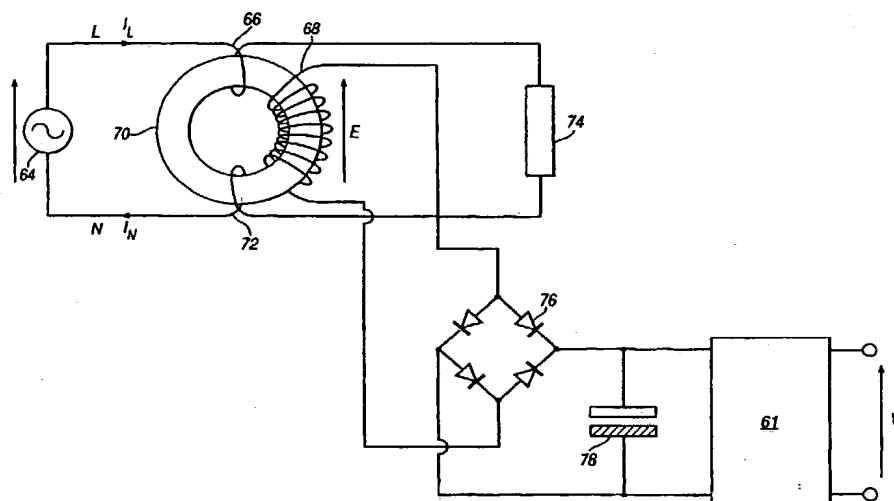


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(57) Abstract

A drive circuit for a residual current device comprises a transformer having a first and second primary coil each having n_1 turns, and a secondary coil having n_2 turns arranged to output a drive voltage responsive to any current imbalance between the respective electric currents flowing in the first and second primary coils. In order to achieve as high a drive voltage as possible the transformer is arranged to saturate at a relatively low level of current imbalance thus causing the back-EMF voltage generated across the secondary coil to spike resulting in a low power high voltage drive signal being output. Preferably, the secondary coil output is rectified, smoothed, and multiplied before being used as a drive signal for an active material bender used as an actuator in a circuit breaker mechanism.

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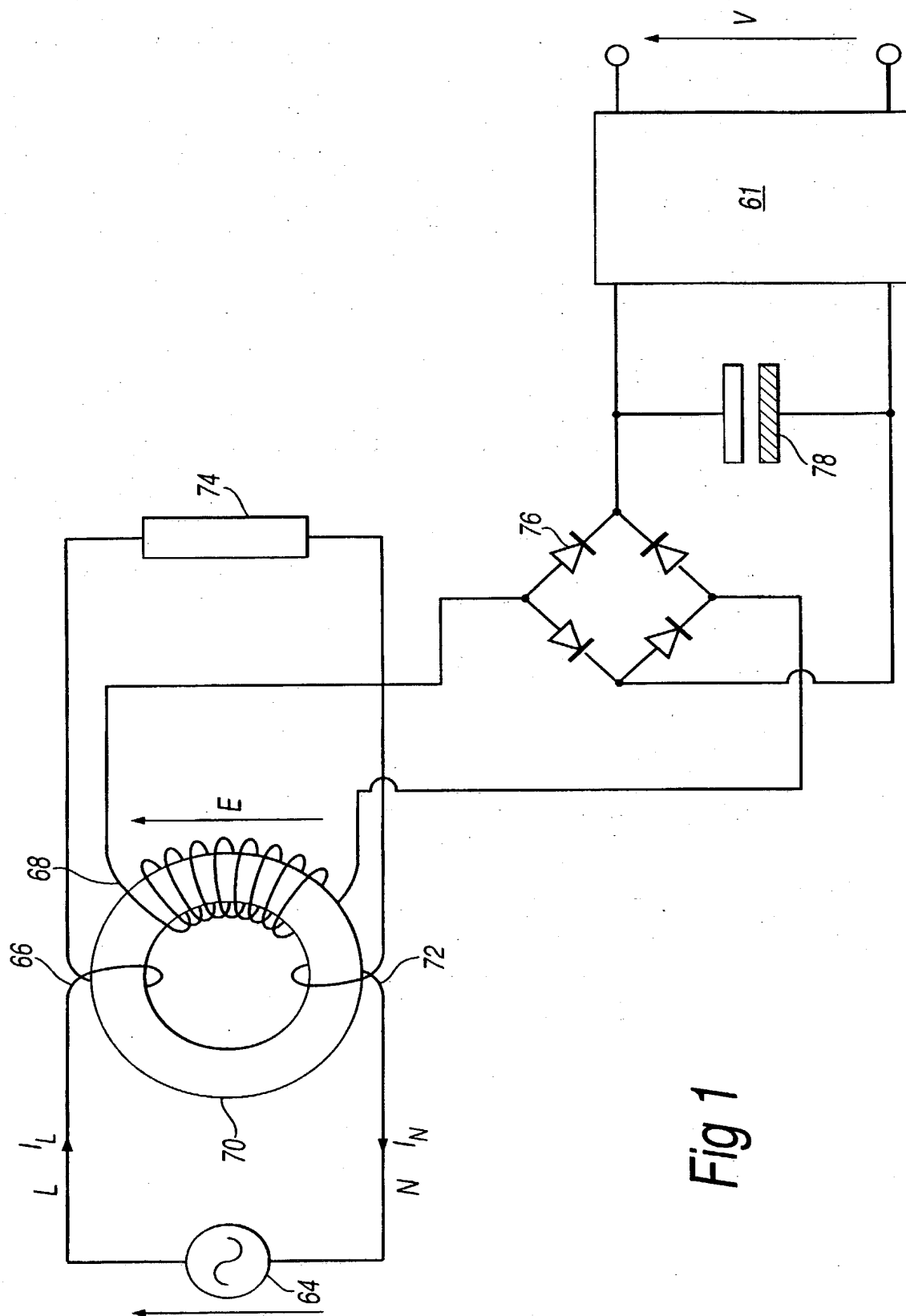


Fig 1

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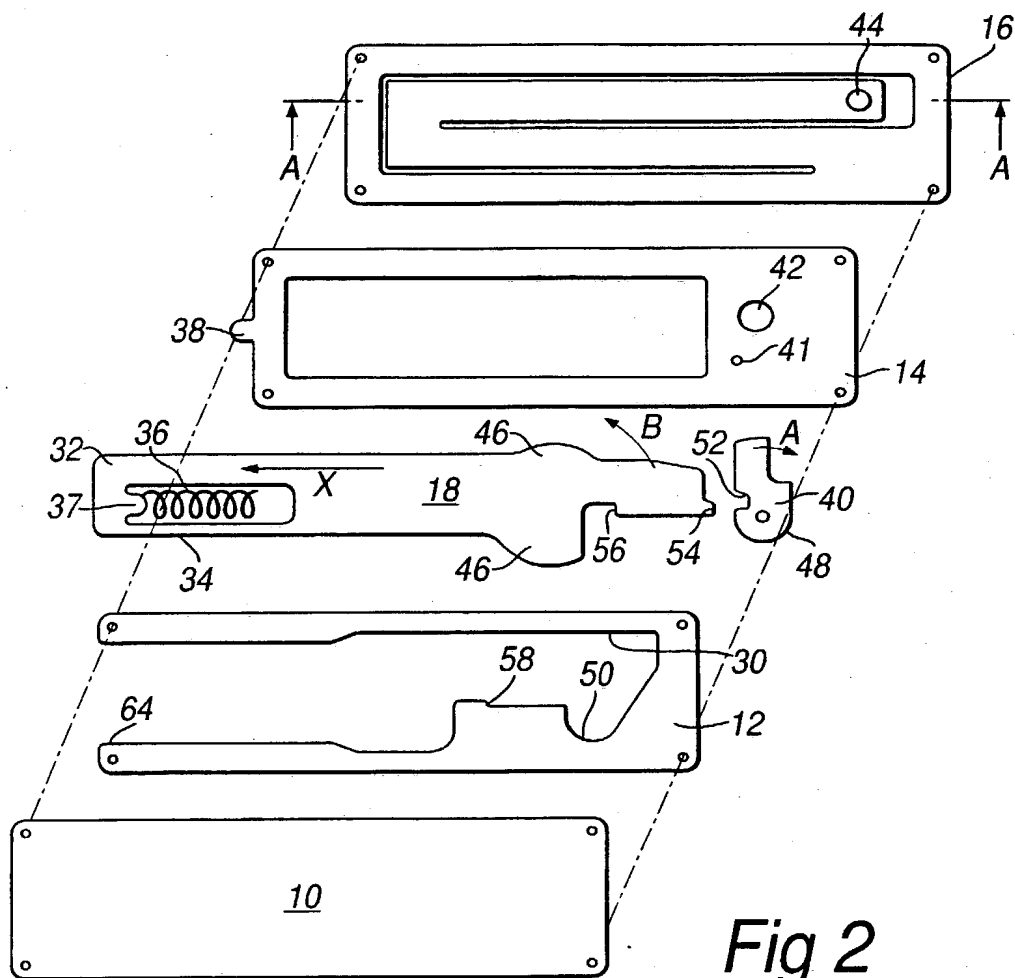


Fig 2

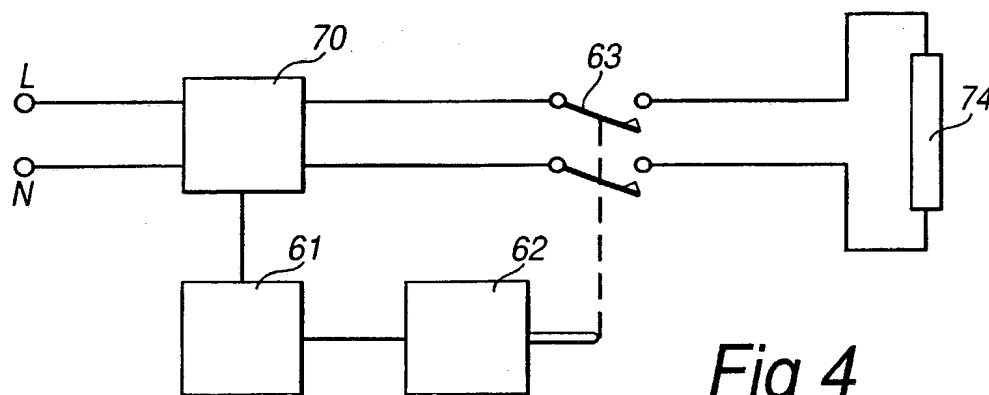


Fig 4

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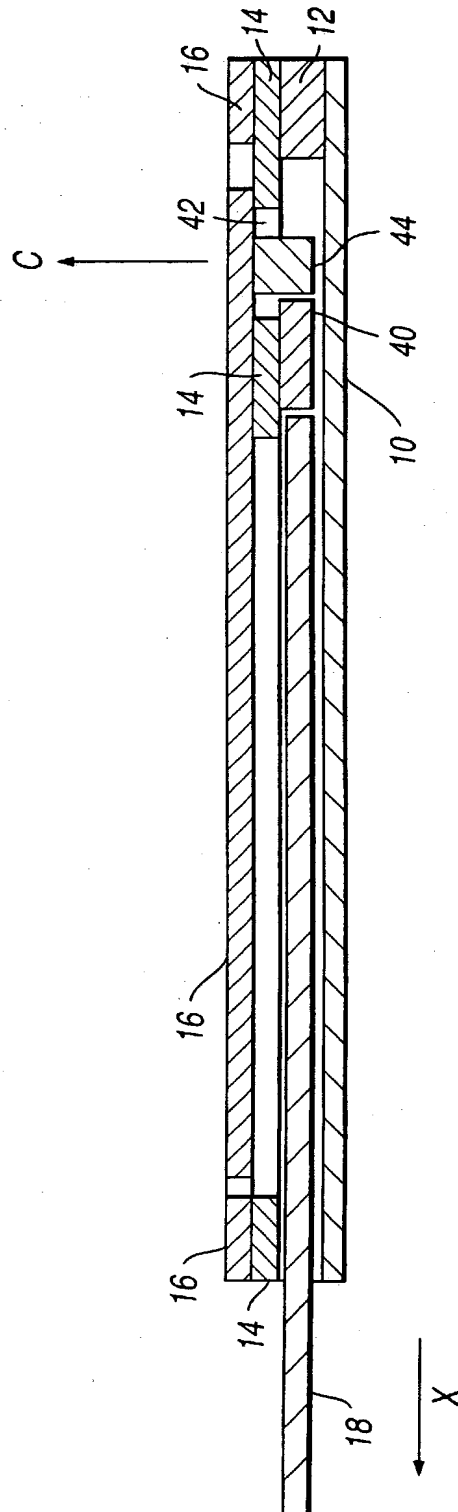


Fig 3

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Declaration, Power of Attorney and Petition

WE (I) the undersigned inventor(s), hereby declare(s) that:

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

INTEGRATED ELECTRICALLY ACTUATED MECHANICAL RELEASE MECHANISM

the specification of which

☐ is attached hereto.

☒ was filed on October 19, 2001 as

Application Serial No. 09/926,352

and amended on _____.

☐ was filed as PCT international application

Number _____

on _____,

and was amended under PCT Article 19

on _____ (if applicable).

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application(s)

Application No.	Country	Day/Month/Year	Priority Claimed
<u>9908930.2</u>	<u>Great Britain</u>	<u>19 April 1999</u>	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
_____	_____	_____	<input type="checkbox"/> Yes <input type="checkbox"/> No

We (I) hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below.

(Application Number)

(Filing Date)

(Application Number)

(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or under §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

Application Serial No.

Filing Date

Status (pending, patented,
abandoned)

PCT/GB00/01508

April 18, 2000

And we (I) hereby appoint the following registered practitioner(s):



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as our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to



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We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Simon POWELL

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Date

5 FEBRUARY 2003